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Self-esteem moderates affective and psychotic responses to social stress in psychosis: A virtual reality study

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ABSTRACT

Background: Higher liability to psychosis is associated with low self-esteem and increased sensitivity to social stress. Recently, we reported a positive relation between liability to psychosis and affective and psychotic responses to social stress. This study investigated how self-esteem moderates paranoia, peak subjective distress and stress reactivity of people with different psychosis liability in response to social stressors in virtual reality.
Methods: Ninety-four individuals with lower (41 siblings and 53 controls) and 75 persons with higher psychosis liability (55 with recent onset psychotic disorder and 20 at ultra-high risk for psychosis) explored five times a virtual café with various social stressors (crowdedness, ethnic minority status, and hostility). They rated momentary paranoia (State Social Paranoia Scale) after each experiment and subjective distress on a visual analogue scale before and after the experiments. Positive and negative self-esteem were assessed with the Self-Esteem Rating Scale.
Results: Momentary paranoia, peak subjective distress, and reactivity to social stressors were associated with negative self-esteem, but not positive self-esteem. Effects of both positive and negative self-esteem on psychotic and affective stress responses, but not stress reactivity, became significantly stronger when individuals were exposed to more stressful environments. Effects of self-esteem on momentary paranoia and peak subjective distress did not differ between the high liability and low liability group. Persons with lower psychosis liability had a stronger effect of negative self-esteem on stress reactivity than persons with higher liability.
Conclusions: Positive and negative self-esteem may play an important role in affective and psychotic responses to social stress.

1. Introduction

Self-esteem can be described as the degree to which one values, approves or likes oneself. It is an affective evaluation of one's own worth, value or importance (Robinson et al., 2013) and also an important determinant of psychological health (Silverstone and Salsali, 2003). Low self-esteem is closely connected to a wide range of psychopathology (Zeigler-Hill, 2011), including depression (Orth et al., 2009), generalized anxiety disorder (Henning et al., 2007), obsessive compulsive disorder (Doron et al., 2008), borderline personality disorder (Zeigler-Hill and Abraham, 2006), and psychotic disorder (Kesting and Lincoln, 2013).

To explain the etiology of the relation between low self-esteem and psychopathological symptoms, two models have been proposed: the vulnerability model and the scar model (Zeigler-Hill, 2011). The vulnerability model proposes that low self-esteem is a risk factor for/a cause of developing psychopathology. The scar model states that low self-esteem is a consequence, not a cause, of psychopathology. The models do not mutually exclude each other, since low self-esteem may be both a cause and a consequence of symptoms. A recent meta-analysis examined the relation between self-esteem, and anxiety and depression, and found more support for the vulnerability model than the scar model: moreover, longitudinal data from both clinical and non-clinical samples demonstrated a significantly stronger effect of self-esteem on depression than of depression on self-esteem (Sowislo and Orth, 2012). High self-esteem protects individuals from developing symptoms, while persons with low self-esteem seem to lack sufficient resources to protect themselves from psychopathology (Zeigler-Hill, 2011). Thus, self-esteem and psychopathology appear to be interrelated networks.

A low level of self-esteem is often seen in patients with a psychotic disorder and is associated with higher levels of specific symptoms,

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such as hallucinations and persecutory delusions (Smith et al., 2006; Romm, 2010; Blairy et al., 2004; Karatzias et al., 2007; Silverstone and Salsali, 2003). In persons with psychosis, researchers found a strong positive association between negative self-esteem and positive symptoms, i.e. a negative self-image is related to more positive symptoms (Barrowclough et al., 2003). Also, a negative relation was found between positive self-esteem and negative symptoms, i.e. a positive self-image is related to less negative symptoms. Thus, self-esteem may be both a risk factor and a protective factor.

Paranoia, a core positive symptom in psychosis, is related to self-esteem (Thewissen et al., 2008; Kesting et al., 2013; Bentall et al., 2009; Atherton et al., 2016). Individuals who show paranoid reactions experience fear in relation to other people and fear of being deliberately harmed by others (Freeman and Garety, 2000; Freeman et al., 2002). In patients with psychosis as well as in the general population, self-esteem was shown to predict the onset of paranoia in daily life, i.e. when self-esteem decreased, levels of momentary paranoia increased (Thewissen et al., 2008; Thewissen et al., 2011; Kesting et al., 2013).

In persons with a psychotic disorder, self-esteem can be strongly negatively influenced by social stress (Lysaker et al., 2008; Gumley et al., 2004). Patients with psychosis are often highly sensitive to stress, which expresses itself in high affective or paranoid reactivity to stress (Lardinois et al., 2011). Stress sensitization may be involved in this process (Howes et al., 2016; Reininghaus et al., 2016; Collip et al., 2008; Myin-Germeys and van Os, 2007; Lardinois et al., 2011). Stress sensitization may develop when individuals are repeatedly exposed to environmental risk factor(s) and develop progressively greater psychological and/or physiological response to stress over time (Collip et al., 2008).

To further investigate affective and psychotic reactions in social situations, exposure to a controlled environment with social stressors is needed. However, the 'real' social environment is difficult to measure, let alone control, because it is highly complex, is never precisely the same, and is strongly influenced by the individual's behavior. By using Virtual Reality (VR), an interactive and immersive 3-dimensional virtual environment can be designed, which changes in response to an individual's movements and actions (Veling et al., 2014a). This enables exposure to a controlled experimental social environment (Veling et al., 2014b; Valmaggia et al., 2016). Characteristics of the virtual environment, including behavior of virtual characters (avatars), can be adjusted, enabling researchers to expose all participants to the same complex social stressors. VR is a safe, feasible and realistic technique to use for patients with psychotic disorders (Rus-Calafell et al., 2018). There is evidence that virtual avatars can induce affective and psychotic reactions (Freeman et al., 2010; Veling et al., 2016; Fornells-Ambrojo and Slater, 2013). Furthermore, exposure to VR, combined with threat belief testing, reduced paranoia levels in patients with a severe mental illness (Freeman et al., 2016). Also, a recent VR study showed that inducing low self-confidence in healthy individuals led to greater levels of paranoia in a neutral virtual environment (Atherton et al., 2016).

Recently, we reported a positive association between psychosis liability and paranoid and affective reactions to social stressors in VR (Veling et al., 2016). Specifically, persons with high liability to develop psychosis, showed, compared to persons with low psychosis liability, higher levels of paranoia and peak subjective distress when the levels of environmental social stress increased. Also, they demonstrated a higher basic level of paranoid thoughts and peak subjective distress. What explains differences in psychotic and affective responses between groups and individuals remains unclear. We theorize, substantiated by above described research, that low self-esteem might be involved. Since self-esteem is a modifiable target of treatment, this finding might be clinically relevant. The present study, using the same dataset as the previous research, investigated the role of self-esteem in levels of psychotic and affective responses to VR social stressors.

We hypothesized that:

1) Positive and negative self-esteem are associated with lower respectively higher momentary paranoia, peak subjective distress, and stress reactivity after exposure to VR social stressors. These effects are stronger when level of social stressors increases;
2) Higher psychosis liability is associated with lower positive self-esteem and higher negative self-esteem. The effects of self-esteem on momentary paranoia, peak subjective distress, and stress reactivity in VR are stronger in the higher psychosis liability group than in the lower psychosis liability group.

2. Methods

2.1. Participants

Participants were aged 18–35 years and were required to have sufficient command of the Dutch language. Exclusion criteria were a history of epilepsy and an intelligence quotient ≤ 75.

Two groups were compiled based on the level of psychosis liability. The group with higher psychosis liability consisted of individuals who were diagnosed with psychotic disorder ≤ 5 years ago. All DSM-IV categories of psychotic disorders were included, with the exception of substance-induced psychotic disorder and psychotic disorder due to a medical condition. Individuals with an ultra-high risk (UHR) to develop a psychotic disorder were also included in the higher psychosis liability group. UHR was determined with the Comprehensive Assessment of the At Risk Mental State (CAARMS) interview (Yung et al., 2003). This semi-structured interview assesses attenuated psychotic symptoms in individuals referred to psychiatric outpatient clinics for symptoms or disorders other than psychosis. UHR was further defined by a lower level of functioning for at least one year, as determined by a score of ≤54 on the Social and Occupational Functioning Assessment Scale (SOFAS) (Goldman et al., 1992).

The group with lower psychosis liability consisted of non-affected siblings of patients with a psychotic disorder; these siblings were not necessarily the siblings of participating patients. This group also included healthy controls, who had never experienced a psychotic episode or disorder, nor had a first-degree relative with a psychotic disorder.

The classification of higher psychosis liability (patients with psychosis and UHR patients) and lower psychosis liability (siblings and healthy controls) was based on presence of phenotype of psychotic symptoms, which is present in both psychosis and UHR patients, but generally absent in siblings and controls; and on life time psychosis-risk, which is higher in psychosis patients and UHR patients (respectively 100% and 36%), than in siblings and controls from the general population (resp. 10% and 3%) (van Os et al., 2009; Fusar-Poli et al., 2013).

Individuals from the group with higher psychosis liability were recruited from psychiatric institutions in the provinces North and South Holland; siblings were approached through patients and family associations. Controls were recruited via vocational education schools and universities for applied sciences in South Holland, and in dental offices.

This study was approved by the Medical Ethics Committee of the Leiden University Medical Centre. All participants signed informed consent. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

2.2. Procedures

All data were collected during the one VR session that each participant took part in; each session lasted about 3 h. First, participants filled out several questionnaires (see Measures). Then they were exposed five times to a VR environment in which they had to perform, each time, the same simple task during a 4-min period. After each of the VR

experiments, participants rated their subjective level of distress and filled in a questionnaire about their momentary paranoia.

2.3. Virtual reality experiments

In this study, the virtual environment (from CleVR BV, Delft, the Netherlands; Fig. 1) was a café in which avatars were standing/sitting, and with typical café noises in the background. Participants could navigate in the virtual environment using a Logitech Chillstream Gamepad. They wore an Emagin Z800 3D Visor with a resolution of SVGA 800 × 600 24 bit, with 40_diagonal field of view, and built-in 3DOF tracker. For more information about VR, see www.vrmentalhealth.nl.

The social stressors involved the number, ethnic appearance and facial emotional expression of the avatars, as described in detail elsewhere (Veling et al., 2016). These factors were manipulated to create five conditions, each with a varying degree of virtual social stress. In the no-stress condition, only six avatars, with mainly the own ethnicity and a neutral facial expression, appeared in the café; in the condition with one stressor, the café was more crowded with forty avatars; the conditions with two stressors added either a majority of avatars having an ethnicity other than the participants', or angry, hostile looking avatars; and the condition with three stressors involved forty hostile avatars of other than own ethnicity.

Participants were given a simple assignment to ensure a closer approach to the avatars, i.e. they were instructed to search for the five avatars who had a number on their shirt (0–99). After the experiment, participants had to report the number and gender of the avatar who had the highest number on the shirt; this assignment was the same in all five experiments. Order effects were controlled for by randomly determining the sequence of the experiments.

2.4. Measures

Self-esteem was measured with the Self-Esteem Rating Scale (SERS) (Nugent and Thomas, 1993), a 40-item measure rated on a 7-point Likert scale. It consists of two subscales: Positive self-esteem and Negative self-esteem; both scales include 20 items, with total scores ranging from −120 to 120. High scores on the positive scale indicate higher or more positive self-esteem, whereas high scores on the negative scale indicate higher or more negative self-esteem. An example of an item in the Positive scale is: '*I feel that I am an attractive person*'. An example of an item in the Negative scale is: '*I feel that others do things much better than I do*'. The scale has high internal reliability (Cronbach's α is 0.97) (Nugent and Thomas, 1993).

Fig. 1. Screenshot of the virtual café.
Source: CleVR BV

Momentary paranoia was assessed after each experiment with the Social State Paranoia Scale (SSPS) (Freeman et al., 2007). This consists of 20 items, divided into two scales. One scale consists of 10 dummy items and the other consists of 10 items that all contain elements of perceived 'threat and intention' of the persecutor. State paranoia is calculated by summing the 10 'threat and intention' items, which are scored on a 5-point Likert scale (ranging from 'do not agree' to 'totally agree'). Internal reliability is high (Cronbach's α is 0.91) (Freeman et al., 2007).

Subjective distress was measured with units on an analogue scale (Subjective Units of Distress; SUD), ranging from 0 to 100. SUDs were reported verbally before, during and after each of the VR experiments.

2.5. Statistical analysis

Data were analyzed using SPSS Statistics v. 22 (IBM Corp, 2012) and Stata v. 13 (StataCorp, 2013). The two psychosis liability groups were tested in SPSS for differences in sociodemographic characteristics by *t*-tests (continuous variables) and chi-square (categorical) tests. We compared gender, age, education level, and ethnicity.

For negative self-esteem, the negative scores were inverted in positive scores to simplify interpretation. For momentary paranoia and peak subjective distress, the mean score of all experiments was used. For stress reactivity, we calculated, for each experiment, the subjective distress score during the experiment minus the distress score before the experiment; subsequently the mean stress reactivity score of all experiments was used. Using the XTREG procedure in Stata, we performed multilevel regression analyses to calculate main effects of positive and negative self-esteem on momentary paranoia, peak subjective distress, and stress reactivity. Psychosis liability, number of stressors, age, gender, and level of education were included as covariates. Differences between the psychosis liability groups in self-esteem, momentary paranoia, peak subjective distress, and stress reactivity were analyzed in SPSS with *t*-tests.

Moderation analyses were performed with multilevel random intercepts regression models, using the XTREG procedure in Stata. We analyzed two different moderation models. First, momentary paranoia, peak subjective distress, and stress reactivity as dependent variables with number of virtual social stressors as independent variable, moderated by positive or negative self-esteem. Second, we analyzed momentary paranoia, peak subjective distress, and stress reactivity as dependent variables with psychosis liability as independent variable, moderated by positive or negative self-esteem. In all analyses, age, gender, and level of education were included as covariates. In addition, in the first model we added psychosis liability, and in the second model the number of virtual social stressors. With the MARGINS DYDX procedure, the interaction terms were compared by estimating linear marginal effects for the different numbers of social stressors and psychosis liability groups.

3. Results

3.1. Demographic data

Ninety-four participants with lower psychosis liability (53 controls, 41 siblings) and seventy-five with higher liability (20 UHR, 55 psychosis) were included. Level of education was significantly lower in the higher liability group, no differences were found in age, gender and ethnicity between the two groups. Demographic data are presented in Table 1.

Table 1
Demographic characteristics of the two study groups ($n = 169$).

	Lower psychosis liability[a] ($n = 94$)	Higher psychosis liability[a] ($n = 75$)
Mean age, years (SD)	25.4 (4.6)	25.4 (4.7)
Male (%)	51.1	65.3
Ethnicity (%)		
Dutch	71.3	58.7
Surinamese	3.2	10.7
Moroccan	2.1	0.0
Turkish	2.1	4.0
Antillian/Aruban	2.1	2.7
Other	19.1	24.0
Educational level (%)*		
No/primary	0.0	4.0
Vocational	25.5	44.0
Selective secondary	14.9	20.0
Higher	59.6	32.0

[a] Lower liability group includes controls and siblings of patients with psychotic disorder. Higher liability group includes individuals at Ultra High Risk for psychosis and patients with recent onset psychosis.
* $p < 0.01$.

3.2. Self-esteem, paranoia, peak subjective distress, and stress reactivity

The main effect of positive self-esteem on momentary paranoia, peak subjective distress, and stress reactivity was not significant (Table 3). The main effect of negative self-esteem on all outcomes was strongly significant; momentary paranoia, peak distress, and reactivity to social stressors increased with level of negative self-esteem. There was a significant difference between the psychosis liability groups in self-esteem, momentary paranoia, peak subjective distress, and stress reactivity scores (Table 2). The group with higher liability psychosis reported a higher negative self-esteem score ($F = 66.083$, $df = 1$, $p < 0.001$) and a lower positive self-esteem score ($F = 50.196$, $df = 1$, $p < 0.001$) than the group with lower liability. Also, the group with higher psychosis liability had higher mean paranoia, ($F = 29.780$, $df = 1$, $p < 0.001$), peak subjective distress ($F = 8.146$, $df = 1$, $p = 0.005$), and stress reactivity scores ($F = 7.588$, $df = 1$, $p = 0.007$) during the VR experiments.

3.3. Interaction between self-esteem and number of virtual social stressors

The multilevel random regression analysis showed a significant negative interaction between positive self-esteem and number of social stressors on paranoia ($B = -0.039$, 95% CI: -0.074; -0.003, $p = 0.031$), peak subjective distress ($B = -0.066$, 95% CI: -0.127; -0.004, $p = 0.037$), but not stress reactivity ($B = 0.009$, 95% CI: -0.057; 0.076, $p = 0.784$). Linear predictions per social stress level showed that protective effects of positive self-esteem levels on paranoia and peak subjective distress were stronger when exposed to more stressors (Table 3).

Interactions between negative self-esteem and number of social stressors were positive and significant on paranoia ($B = 0.055$, 95% CI: 0.024; 0.086, $p < 0.001$) and peak subjective distress ($B = 0.081$, 95% CI: 0.027; 0.134, $p = 0.003$), but not stress reactivity ($B = 0.029$, 95% CI: -0.029; 0.088, $p = 0.323$). The effects of negative self-esteem on paranoia and peak subjective distress were stronger when social stress increased (Table 3).

3.4. Interaction between self-esteem and psychosis liability

Interactions between positive self-esteem and psychosis liability on paranoia ($B = 0.088$, 95% CI: -0.152; 0.328, $p = 0.473$), peak subjective distress ($B = 0.035$, 95% CI: -0.696; 0.765, $p = 0.926$), and stress reactivity ($B = 0.079$, 95% CI: -0.271; 0.429, $p = 0.658$) were not significant.

Interactions between negative self-esteem and psychosis liability on paranoia ($B = -0.041$, 95% CI: -0.240; 0.157, $p = 0.682$) and peak subjective distress ($B = 0.129$, 95% CI: -0.468; 0.725, $p = 0.673$) were not significant. However, the interaction was negative and significant on stress reactivity ($B = -0.400$, 95% CI: -0.683; -0.117, $p = 0.006$), which means that the effect of negative self-esteem on stress reactivity was stronger in the lower psychosis liability group than in the higher liability group (Table 3).

4. Discussion

This Virtual Reality study investigated the role of self-esteem in social stress responses. We found that negative self-esteem was associated with more paranoia and subjective distress in response to social stressors. These effects were stronger when level of environmental social stress increased, and were independent of psychosis liability. The impact of negative self-esteem on stress reactivity was stronger in persons with lower psychosis liability than in those with higher liability. Positive self-esteem reduced the impact of increasing social stressors on level of subjective distress.

Our results implicate that negative self-esteem might lead to a heightened paranoid and stressed reaction when exposed to social stress, while positive self-esteem may serve as a buffer when social stress increases. This is in line with previous studies. By using ecological momentary assessments, researchers showed that fluctuations in self-esteem predicted levels of paranoia in daily life (Thewissen et al., 2008; Thewissen et al., 2011). Going out on a busy street (Freeman et al., 2014) as well as a critical attitude of family members (Barrowclough et al., 2003) were related to more symptoms in patients with psychosis, which were mediated by negative self-beliefs. A VR study in a general population sample provided experimental evidence of increased paranoia in a neutral virtual environment after inducing a decrease in self-confidence (Atherton et al., 2016). Another study found in a non-clinical sample that paranoid beliefs increased when individuals were socially excluded in a virtual ball game, and that this association was mediated by a decrease in self-esteem (Kesting et al., 2013). Thus, the social environment can have a negative influence on self-esteem, leading to higher levels of paranoia and distress. As having a psychotic disorder also leads to more negative self-beliefs and more exposure to social stress, a vicious circle of psychosis liability, low self-esteem, social stress sensitization and affective and psychotic symptoms may develop (Kesting and Lincoln, 2013).

In contrast to what we had expected, the relation between negative self-esteem and stress reactivity was stronger in individuals with lower psychosis liability than in persons with higher psychosis liability. This might be due to a ceiling effect in the high liability group. In the high liability group, stress levels were already high at the start of exposure to the virtual environment. Therefore, an increase during the exposure was evident but limited, as opposed to the low liability group which

Table 2
Self-esteem, momentary paranoia, peak subjective distress and stress reactivity, by psychosis liability.

	Lower psychosis liability			Higher psychosis liability		
	Mean	SD	Range	Mean	SD	Range
	(n = 94)			(n = 75)		
Positive self-esteem***	55.1	7.1	35–70	42.5	12.8	11–69
Negative self-esteem***	21.4	8.4	10–50	34.7	15.6	10–66
State paranoia**	16.8	6.9	10–40	20.1	8.1	10–44
Peak subjective distress***	23.6	18.5	0–83	42.8	27.2	0–100
Stress reactivity**	7.4	8.4	−3–50	11.4	9.2	−7 - 48

SD = standard deviation.
** $p < 0.01$.
*** $p < 0.001$.

Table 3
Self-esteem as moderator of social stress level and psychosis liability on paranoia, peak subjective distress and stress reactivity.

	Paranoia			Peak subjective distress			Stress reactivity[a]		
	B	95%CI	*p* value	B	95% CI	*p* value	B	95% CI	*p* value
Positive self-esteem	−0.003	−0.111 to 0.105	0.956	−0.294	−0.630 to 0.042	0.086	−0.135	−0.294 to 0.023	0.095
Negative self-esteem	0.155	0.060 to 0.250	<0.001	0.591	0.298 to 0.884	<0.001	0.198	0.057 to 0.340	0.006
Positive self-esteem x number of virtual social stressors[b]	−0.039	−0.074 to −0.003	0.031	−0.066	−0.127 to −0.004	0.037	0.009	−0.057 to 0.076	0.784
No stressor	0.054	−0.066 to 0.174	0.377	−0.197	−0.545 to 0.151	0.268	–	–	–
1 stressor	0.015	−0.094 to 0.125	0.784	−0.262	−0.600 to 0.075	0.127	–	–	–
2 stressors	−0.024	−0.133 to 0.086	0.674	−0.328	−0.666 to 0.009	0.057	–	–	–
3 stressors	−0.062	−0.183 to 0.059	0.312	−0.394	−0.743 to −0.045	0.027	–	–	–
Negative self-esteem x number of virtual social stressors[b]	0.055	0.024 to 0.086	<0.001	0.081	0.027 to 0.134	0.003	0.029	−0.029 to 0.088	0.323
No stressor	0.075	−0.030 to 0.180	0.163	0.472	0.168 to 0.775	0.002	–	–	–
1 stressor	0.130	0.034 to 0.226	0.008	0.552	0.258 to 0.846	<0.001	–	–	–
2 stressors	0.185	0.089 to 0.282	<0.001	0.663	0.338 to 0.927	<0.001	–	–	–
3 stressors	0.240	0.134 to 0.347	<0.001	0.713	0.409 to 1.017	<0.001	–	–	–
Positive self-esteem × psychosis liability[c]	0.088	−0.152 to 0.328	0.473	0.035	−0.696 to 0.765	0.926	0.079	−0.271 to 0.429	0.658
Negative self-esteem × psychosis liability[c]	−0.041	−0.240 to 0.157	0.682	0.129	−0.468 to 0.725	0.673	−0.400	−0.683 to −0.117	0.006
Lower psychosis liability	–	–	–	–	–	–	0.502	0.246 to 0.757	<0.001
Higher psychosis liability	–	–	–	–	–	–	0.102	−0.052 to 0.255	0.194

[a] Subjective distress during experiments minus distress before experiments.
[b] Overall effect; adjusted for age, gender, educational level, and psychosis liability.
[c] Overall effect; adjusted for age, gender, educational level, and number of stressors.

had a lower baseline level of stress and therefore a larger margin to react to the stressors.

Since depression is strongly associated with self-esteem (Watson et al., 2006; Freeman and Garety, 2003), it could be argued that depression should be taken into account as a covariate in the moderation analyses, i.e. depression could confound the relation between the independent/dependent variables. However, a recent meta-analysis found a significant stronger effect of self-esteem on depression than vice versa (Sowislo and Orth, 2012). Also, in a longitudinal study of patients with psychotic disorders, the link between depressed mood and paranoia was mediated by negative self-evaluations, also suggesting a distinct and central role for self-esteem in the development and maintenance of paranoia (Fowler et al., 2012).

This study has several limitations. First, our results might be interpreted to be in line with the vulnerability model of self-esteem (Zeigler-Hill, 2011), in which low self-esteem is a risk factor for developing a variety of psychopathological symptoms. However, because our study did not have a longitudinal design (all experiments were conducted during one session and self-esteem was measured once at baseline), the results should be interpreted with caution; cause and effect cannot be completely disentangled. Second, as a self-report measure was used for self-esteem, this might have led to socially desirable answers that could overestimate or underestimate the results. Third, the present study used VR to investigate the influence of a social situation on several outcomes. However, virtual environments are not real and participants might not respond to virtual environmental stressors in the same way as in a real-life situation. To be able to adequately adjust in the virtual environment and to react naturally to social stressors, participants should feel a sense of presence in the virtual world. However, since the avatars in our study were not very realistic and the environment was less complex than the real world, participants may not have felt a strong sense of presence in VR and may not have reacted the way they would in real life. Nevertheless, since VR has been shown to have high ecological validity (Veling et al., 2014b; Veling et al., 2014a) this potential limitation is likely to be small.

A main strength of VR is that the technique ensures that the environmental exposures are the same for every participant. Exposures are controlled and can be repeated. VR is feasible and safe for participants with a psychotic disorder. A review showed that real-life experiences and VR responses are correlated (Veling et al., 2014b). This makes VR a reliable and ecologically valid technique with high potential for experimental studies.

4.1. Clinical implications

When translating these results into clinical practice, improvement of the negative self-image in individuals who are highly liable for psychosis may lead to lower distress and paranoia in social situations. In addition to treating psychotic and affective stress responses, self-esteem interventions should be included in therapeutic protocols for psychosis (Kesting and Lincoln, 2013). This may contribute to breaking the vicious circle of psychosis liability, low self-esteem, stress sensitization, and psychotic symptoms. Cognitive behavioral therapy (CBT) may be effective for improving self-esteem in patients with psychotic disorders, as well as interventions that target self-esteem more explicitly (Laithwaite et al., 2007; Lincoln et al., 2012). Improving self-esteem may reduce not only paranoia but also other symptoms. Further research should clarify whether treating self-esteem does in fact reduce social distress and paranoia in daily life.

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Conflict of interest
None.

Contributors
Authors RPK, MvdG and WV designed the study. RPK wrote the protocols. AJ, RPK and JC carried out research appointments. Authors AJ and WV carried out statistical analysis and AJ wrote the first draft of this manuscript. All authors contributed to and have approved this manuscript.

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